GROWTH OF BODY COMPONENTS IN PARENT-AND HAND-REARED CAPTIVE KESTRELS

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Abstract

Twelve female and 13 male American Kestrels (*Falco sparverius*) were hand-reared and fed to satiation 4 times daily. The growth of the tarsus, third toe, manus, antebrachium, bill, and skull, as well as body weight, were measured every 6 days up to fledging and compared to identical measurements recorded from 8 female and 11 male kestrels raised naturally by captive parents provided a similar but *ad libitum* diet. Parent-raised birds grew more rapidly and achieved greater body size than hand-reared birds. Males grew faster than females for most parameters, particularly toe and tarsus length.

Introduction

With the advent of captive breeding programs for falcons, both for laboratory research (Bird and Rehder 1981, Bird 1982) and release into the wild (Newton 1979), the demand for information on the nutritional health of captive-raised falcons is increasing.

Ricklefs (1968) felt that nutritional deficiencies may affect growth rates of wild birds and advised that only growth data collected under favourable conditions be used for comparative purposes. Furthermore, he suggested that hand-rearing techniques could prove to be valuable in this regard. Olendorff (1974) pursued this suggestion in a laboratory investigation of 3 buteo species, but has not provided comparative growth data for birds raised naturally by their wild parents.

We had the opportunity to compare patterns of growth of body components of captive American Kestrels (*Falco sparverius*) raised by parent birds with those hand-reared by humans. The major source of variability between the two groups was food availability, i.e., hand-reared birds were fed to satiation 4 times daily, and parent-raised birds had *ad libitum* food supply. Thus, our objectives were: 1) to describe growth of selected body components in the kestrel and to contrast these patterns with those of other raptorial species; 2) to assess the effect of food availability as a result of hand-rearing on growth patterns; and 3) to compare the growth rates of male and female kestrels.

Materials and Methods

All kestrels were offspring bred from stock at the Macdonald Raptor Research Centre of McGill University in Ste. Anne de Bellevue, Quebec. Eight females and 11 males raised by parents from naturally-incubated eggs were randomly selected for measuring from nestboxes in 6 and 8 hreeding pens respectively, comprising a total of 9 different broods. Twenty-five (12 females and 13 males) were randomly selected from offspring being hand-reared from artificially-incubated first clutches. Pens and management practices have been described elsewhere (Bird *et al.* 1976).

Hand-rearing techniques were as follows. After day 1 in the hatcher maintained at 36.5°C, chicks were moved to a styrofoam chest which was thermostatically heated by electrical heating tape or poultry heating elements. A tray of distilled water covered by wire mesh was kept on the brooder floor. The chicks were kept in wire corrals or in soup bowls, each bird identified by non-toxic felt marker pens. The brooder temperature was initially set at 35°C and was decreased every few days until room temperture was reached at 2 weeks. When pinfeathers showed, the chicks were transferred to a plastic swimming pool lined with wood shavings. They eventually fledged into a room 6.6 x 6.6 x 2.5 m with a floor of sand and wooden perches.

Between 18 and 24 hrs after hatching, the chicks were fed small pieces of neonatal mice by blunt forceps. This continued 4 times per day approximately every 4 hours beginning at 0830 hrs, each time to the point of satiation. After about 10 days, they were fed day-old cockerels and, occasionally, laboratory mice. During this period, cockerels without down, beaks and legs, or mice without skin and tails were mashed in a Waring blender with vitamin and calcium supplements added daily. When the young were able to feed themselves, at approximately 14 days, the cockerels or mice were blended whole to provide roughage. As the kestrels approached fledging age at about 25 days, the food was mashed less until whole unmashed cockerels were provided.

The kestrels raised by their parents relied completely on their parental food supply: day-old cockerels and laboratory mice dipped in bonemeal and/or vitamin supplements provided *ad libitum*. Food consumption was not recorded for either hand-reared or parent-raised birds. Rather, the major difference in feeding regimes was food availability: continuous parental attention to begging young versus hand-feeding 4 times per day maximum.

Linear measurements were taken on the left side of the body with a Vernier caliper accurate to 0.1 mm. The following measurements were taken (see Olendorff 1972): 1) tarsal length, 2) antebrachial length, 3) bill depth, 4) skull width, and 5) bill length.

The last 3 measurements were taken as follows: 6) third toe length — the distance from the joint between the distal end of the tarso-metatarsus and the basal phalanx of the third toe, to the distal joint before the point where the talon emerges from the toe. (We decided not to force open the entire toe, including the casing around the talon, to prevent any damage to the foot bones. Therefore, the last section of the toe encasing the talon was omitted from the overall toe length.) 7) manus length — the distance between the wrist and the tip of the third phalanx approximated by the base of the primary feathers growing from the manus. 8) body weight — weight recorded to 0.1 g on a top-loader balance.

The first measurements were taken within 24 hr of hatching and subsequently every 6 days until fledging. Birds undergoing measuring generally had empty crops. The means and standard errors of the 8 body components were calculated 1,7,13,19,25 and 31 days post-hatching for parent- (PR) and hand-reared (HR), male and female kestrels. Mean body sizes of PR and HR kestrels were compared, sexes separately, within 24 hours post-hatching using the Mann-Whitney U test (Siegel 1956). An analysis of variance (Steel and Torrie 1960) was used to locate significant differences in body sizes and growth rates of PR and HR of both sexes. For each sex-rearing combination, body weights at day 25 and 31 were compared to locate significant decays (Ricklefs 1973) and growth rates using the Mann-Whitney U test (Siegel 1956).

The growth rate (K) and asymptote (A) of each component were computed for PR and HR birds by sex grouping according to the logistic model of Ricklefs (1967). For body weight, time for growth between 10 and 90% of the asymptote (t_{10-90}) and the ratio (R) between the asymptote and adult weight were calculated (Ricklefs 1967).

Results

Significant differences between PR and HR male kestrels were evident within 24 hrs of hatching for antebrachium (PR > HR) and manus length (PR < HR), as well as body weight (PR > HR) (Table 1). No significant differences were obtained for females at hatching.

There were significant differences in mean body component sizes of PR and HR, male and female kestrels (Table 2, Fig. 1). Furthermore, the significant age-rearing interactions demonstrated that PR kestrels grew faster than HR kestrels for all components except female skull width and bill length, as well as bill depth of both sexes (Table 2, Fig. 1).

The asymptotes (A), growth rates (K), and adult body sizes of the 7 skeletal measures are shown in Table 3. With the exceptions of female bill and toe lengths, where the asymptotes of HR birds were ≥ PR birds, the asymptotes and growth rates of PR birds exceeded those of HR birds. With respect to growth rate, these findings were consistent with the results shown in Table 2.

The growth rates of males were greater than females for 5 components (Table 3). This trend was most pronounced in development of toe and tarsus and least pronounced in manus and

Table 1. Mean body size (1 standard error) of parent-reared (PR) and hand-reared (HR) American Kestrels within 24 hrs post-hatching.

Body size Component	Male		Female	
	HR[a]	PR[a]	HR[a]	PR[a]
Skull width (cm)	1.56 (.03)	1.51 (.02)	1.50 (.04)	1.49 (.02)
Bill length (cm)	0.63 (.01)	0.64 (.01)	0.63 (.01)	0.64 (.01)
Bill depth (cm)	0.59 (.01)	0.59 (.01)	0.59 (.01)	0.60 (.01)
Tarsus length (cm)	1.41 (.02)	1.40 (.02)	1.36 (.02)	1.38 (.03)
Toe length (cm)	0.55 (.02)	0.62 (.01)	0.56 (.02)	0.58 (.01)
Antebrachium length (cm)	1.20* (.03)	1.12 (.08)	1.17 (.03)	1.16 (.04)
Manus length (cm)	1.36** (.03)	1.49 (.02)	1.40 (.04)	1.43 (.02)
Weight (g)	9.65** (.14)	10.96 (.12)	9.92 (.17)	9.99 (.31)

[a] sample sizes: HR ♂, 13; PR ♂, 11; HR ♀, 12; PR♀, 8.

*,** means of PR and HR kestrels are significantly different, Mann-Whitney U test, $P < 0.05$(*) and $P < 0.01$ (**).

Table 2. Analysis of variance of 8 body components of captive male and female American Kestrel nestlings. The main effects in the analysis are age and rearing; one interaction term (age-rearing) is analyzed. Values are F-test statistics and are significant ($P < 0.01$) unless otherwise specified.

Body parameter	Male			Female		
	Age	Rearing	Age-Rearing	Age	Rearing	Age-Rearing
Skull width	165.3	17.0	4.5	134.3	7.6	1.9 NS
Bill length	386.3	57.3	3.4	345.6	23.1	1.3 NS
Bill depth	190.6	14.9	1.5 NS	145.0	8.0	0.8 NS
Tarsus length	868.5	97.8	7.8	576.8	49.0	4.4
Toe length	487.5	74.5	4.5	415.7	26.6	3.8
Antebrachium length	761.1	62.6	7.7	537.0	42.9	3.4
Manus length	702.3	56.4	5.3	628.1	28.3	3.5
Weight	499.9	136.1	15.1	374.6	61.6	10.6

NS Not significant.

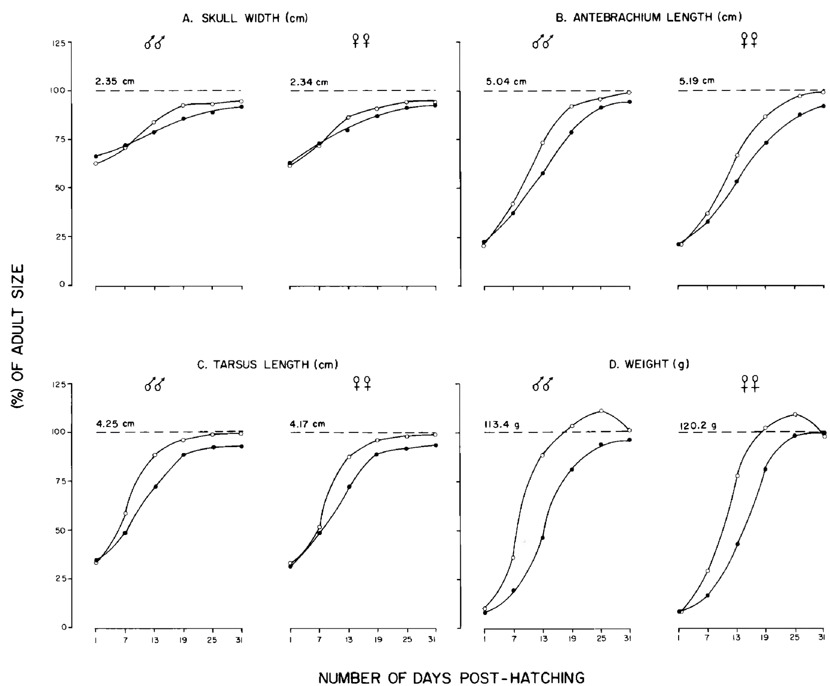

Figure 1. Growth of parent-reared (open circles) and hand-reared (closed circles), male and female, American Kestrels expressed as a percentage of adult size. Mean adult size, determined from parent-reared kestrels, is indicated along the top of each dashed line for: A. skull width; B. antebrachium length; C. tarsus length, and; D. body weight.

Table 3. Asymptotes (A) and growth rates (K) of 7 body components (cm) of parent-raised (PR) and hand-reared (HR) American Kestrels and associated mean (1 standard error) adult body sizes.[a]

	Male				
Body Component	HR(13)[b]		PR(11)		
	A	K	A	K	Adult[c](72)
Skull width	2.24	.079	2.30	.121	2.35(.02)
Bill length	1.21	.091	1.22	.131	--
Bill depth	0.94	.116	0.97	.125	0.89(.01)
Tarsus length	4.12	.165	4.29	.207	4.25(.04)[d]
Toe length	1.59	.188	1.71	.228	2.06(.03)
Antebrachium length	5.08	.143	5.27	.175	50.04(.03)
Manus length	5.49	.150	5.53	.172	--

	Female				
Body Component	HR(12)		PR(8)		
	A	K	A	K	Adult[c](69)
Skull width	2.25	.087	2.27	.134	2.34(.01)
Bill length	1.22	.096	1.22	.120	--
Bill depth	0.96	.103	0.98	.115	0.93(.01)
Tarsus length	4.19	.146	4.36	.182	4.17(.03)[d]
Toe length	1.69	.150	1.68	.182	2.01(.02)
Antebrachium length	5.15	.137	5.35	.172	5.19(.03)
Manus length	5.43	.147	5.59	.164	--

[a] A and K based on pooled data.
[b] sample size indicated in parentheses.
[c] mean adult size (1 standard error) from Bird, unpubl. data, of PR kestrels.
[d] sample sizes are: ♂, 11; ♀, 10.

antebrachium. The growth constant of skull width for females was greater than for males, but no consistent pattern was evident with bill length.

Asymptotes and growth constants for body weight of PR birds were substantially greater than those of HR birds (Table 4). Rate of weight gain of males exceeded females. Although weight was an extremely variable component, females were approximately 6 g heavier than males at, and subsequent to, fledging (Table 4).

Based on the predictive model of Ricklefs (1968: 436), the $t_{10\text{-}90}$ values of males and females would be 15.3 and 15.5 days respectively. However, our corresponding calculated values for PR males and females were 17.6 and 18.4 days. Therefore, weight gain of captive kestrels was relatively slow. The weight loss observed between days 25 and 31 post-hatching

Table 4. Asymptote (A), growth rate (K), number of days required for growth between 10% and 90% of asymptote $t_{10\text{-}90}$) and the ratio (r) of the asymptote to adult size for weight (g) of parent-reared (PR) and hand-reared (HR) American Kestrels.[a].

Growth parameter	Male		Female	
	HR(13)[b]	PR(11)	HR(12)	PR(8)
A	118.9	132.6	130.1	137.7
K	.209	.250	.203	.239
$t_{10\text{-}90}$	21.0	17.6	21.6	18.4
Adult weight (S.E.)[c]		113.4(2.0)		120.2(5.3)
R	1.05	1.17	1.08	1.15

[a] based on pooled data.

[b] sample size indicated in parentheses.

[c] weight (1 standard error) based on 25 ♂ and 26 ♀ from Bird, unpubl. data, on parent-reared birds only.

(Fig. 1) was also reflected in the ratios of the asymptote to adult weight ($R > 1.0$), signifying that the decay phase continues through the early post-fledging period (Table 4).

In Figure 1, growth of PR and HR, male and female kestrels is expressed as the percentage of adult body size. At 31 days post-hatching, skull width had not achieved adult size (Fig. 1a), its growth to be completed following fledging. The K values for tarsus length were higher for the PR birds and for males than for the HR birds and for females, respectively (Fig. 1c). Rapid growth of the antebrachium, primarily between 7 and 19 days post-hatching, resulted in PR nestlings achieving roughly 98.5% of adult size at fledging (31 days) (Fig. 1b). HR birds lagged behind PR birds by approximately 5.5% at this date. The maximum weight of PR kestrels at 25 days post-hatching was followed by a significant weight loss or decay ($P < 0.05$; Fig. 1). A decay phase for HR birds was not observed.

Discussion

The values of A, K, $t_{10\text{-}90}$ and R as shown for body weight in Table 3 are somewhat less than those computed by Ricklefs (1968) from data published by Roest (1957) for 13 wild kestrels from 3 broods. This is especially true for our HR birds. Bird and Laguë (1982) showed that their HR kestrels were permanently smaller as adults than PR ones in skull width, tarsal length, antebrachium and manus length, but not body weight.

In this study, the A and K values, as well as the means of body components, indicated that PR birds grew more rapidly and achieved greater size than HR birds. Since both PR and HR birds received a similar diet, we conclude that differential feeding rates were the main factor limiting rates of growth. We cannot disprove the possibility that different incubation regimes, i.e. natural vs. artificial, for PR and HR birds respectively may have contributed some variation, although Bird and Laguë (1982) noted no effect of incubation technique on fresh chick weight in their captive kestrels.

Our results suggest that for raptors, food limitation can prolong nesting period or result in smaller offspring, as shown in swifts (Lack and Lack 1951) procellariiforms (Lack 1948), and

Red-winged Blackbirds (*Agelaius phoeniceus*) (Dyer 1968). Smaller sizes are often equated with lowered survival probabilities of offspring (Perrins 1965, Thomsen 1971). Although Balgooyen (1976) found no differences in rates of body weight growth of wild kestrels associated with observed differences in feeding rates, he noted that food was likely not a limiting factor, especially when young received food from both parents.

The significant decay in body weight which occurred immediately prior to fledging concurs with Olendorff's (1974) findings in 3 buteo species. The most tangible hypothesis proposed to explain this phenomenon is that substantial water loss occurs as feathers and muscle tissues mature immediately prior to fledging (Ricklefs 1968). It is unlikely that adults starve nestlings to cause nest abandonment (Sumner 1929, Welty 1979), since hand-reared birds exhibit this weight loss (Olendorff 1974, Schmutz and Schmutz 1975, Bird and Laguë 1982).

Growth rates of males, particularly the third toe and tarsus, were greater than those of females. The Cooper's Hawk (*Accipiter cooperi*) and Red-tailed Hawk (*Buteo jamaicensis*) also exhibited this phenomenon (Ricklefs 1968). To explain this pattern in the Sparrowhawk (*Accipiter nisus*), Newton (1978) hypothesized that in species where the male is smaller than the female, the male grows more rapidly to avoid, or reduce, competition in the nest. Werschkul and Jackson (1979) argued that sibling competition is an important determinant driving the evolution of avian growth rates. We found growth in leg components of males faster than females in both rearing groups, which presumably makes smaller males more mobile and potentially able to leave the nest sooner. However, relationship between size of bird and length of development time derived from numerous families of avian species (Ricklefs 1973) may be sufficient to explain these trends. Thus, we believe further research examining competitive interactions among siblings is required to demonstrate that growth rates are a consequence of natural selection acting to reduce competition (see Ricklefs 1982).

In conclusion, food limitation resulted in slower growth rates and smaller body sizes through 31 days of age in captive kestrels. One must be cautious in using hand-rearing techniques for growth studies and propagation of captive avian species for release into the wild.

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THE PRICE OF SUCCESS IN GOSHAWK TRAPPING

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Abstract

Four Swedish traps for goshawks are described. Falling-end traps were most successful of 3 live-bait trap types, but were more expensive to build and less easily moved than sprung-roof